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Relationships Of Red Pine

Seed Source, Seed Weight, Seedling Weight, And Height Growth In Kane Test Plantation

by

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In 1928 the Lake States Forest Experiment Station of the U. S. Forest Service began studies of various races or strains of red pine (Pinus resinosa Ait.), to find out how well red pine is adapted to climatic regions distant from its natural seed sources.

Seed has been collected from 144 or more seed sources throughout the natural range of red pine in the United States. These seed sources represent many different geographic localities, each with its own peculiar soil, forest type, and climatic conditions.

Detailed tests of the seed and the nursery behavior of the seedlings have been made by the Lakes States Station,

and test plantations have been established at several localities in the Lake States (10, 11)[1] and at the Kane Experimental Forest in Elk County, Pa.

Fifty different seed collections were represented in the Kane plantation. Most of them were small groups of mother trees or stands in limited localities, but 22 were single trees for which parent-tree characteristics could be studied. In general the mother trees or groups of trees ranged in age from 30 to 250 or more years, in diameter (d.b.h.) from 8 to 30 inches, and in height from 20 to 102 feet. Some were open-grown, some were forest-grown. In quality, as judged by bole form, they ranged from poor to excellent.

As a result of the tree-race study, the seed sources were grouped into 12 climatic seed-source regions (4). Eight of these are in the Lake States and one each in Maine, Massachusetts, New York, and Pennsylvania.

In the course of this tree-race experiment at the Kane plantation, studies were made of three associated questions in the use of red pine seed and seedlings:

1. The relationship between seed source and seed weight.
2. The relationship between seed weight and seedling development.
3. The relationship between seedling weight and height growth.

SEED SOURCE & SEED WEIGHT

The results of laboratory and nursery tests of the seed from the 50 red pine seed sources are given in table 1. These data were compiled by the Lake States Forest Experiment Station.

Analysis of these data shows that except for seed weight there is apparently no correlation between seed characteristics or nursery behavior and the region the seed

[1] Underlined numbers in parentheses refer to Literature Cited, page 13.

source is located in. Even seed weight is not an infallible guide to region of seed origin. Seed certification is still necessary to establish the source of seed for forest planting.

SEED WEIGHT & SEEDLING DEVELOPMENT

Importance Of Seed Weight

There is much evidence from past studies of crop plants used in agriculture that large seeds produce larger and more vigorous plants than comparable small seeds. Tree-seed studies show similar trends. In particular, studies of the seeds of the oaks, which are relatively large and are not complicated by heavy external coverings, have shown positive correlations between the size and weight of acorns and the size and weight of the resulting progeny.

One of the earliest studies was conducted by Nestrov in the nursery of the Moscow Agricultural College during the spring of 1914 (2). He found that greater acorn weight resulted in greater total seedling weight the following spring. Shoot length was dependent on acorn weight to a greater extent than root length. Heavier acorns produced heavier root system in particular. Korstian (5) studied white, red, chestnut, and black oak seedlings from large, medium, and small acorns. He found that differences in seedling growth during the first season, as well as total germination and survival, were in favor of the large or heavier acorns. McComb (6) found similar results with 1-year chestnut oak seedlings in New Jersey.

For the lighter seeds of the pines, European studies have indicated that seed weight is an important factor in the early period of seedling development. It remained for Mitchell (7, 8), Gast (3), and Mitchell and Rosendahl (9) to show that "reserve dry weight of seed," rather than "green weight of both seed and seed coat," was a more exact measure to use in detailed studies of tree seed and growth of seedlings. Mitchell (8) says that "Seed weight, which exerts an important control on the early cumulative dry weight of pine seedlings, is a very important factor that must be taken into consideration if accurate comparisons are to be made of the results of different experiments with seeds of varied

size and source... Reserve dry weight, which is the dry weight of the seed less the dry weight of the seed coat and with which seedling yield is directly and highly correlated, is the more precise measure of the material available for the development of the embryo."

Gast (3) studied Scots pine (Pinus silvestris) in Sweden and at the Harvard Forest and obtained results comparable to those Mitchell got regarding the influence of seed weight on seedling development.

Mitchell and Rosendahl (9) reported on nursery-grown seedlings of white and red pine developed under different intensities of solar radiation. In this study control of the seed-size factor was found to lead to superior precision of results in comparison to sowings in which the seeds varied as much as 6.0 mg. above and below the mean. When the largest and smallest seeds differed by about 12 mg. this difference alone was "sufficient to account for variations of 30 percent in the dry weights of the resulting seedlings. Deviations of this magnitude necessarily affect the precision of experimental data, especially when the number of observations is limited."

Bates (1) observed variations in the nursery behavior of red pine seed collections and suggested that the purchase of cones by weight, rather than by volume, would probably provide better seed for large-scale nursery operations.

Seed Weight & Dry Weight Of 2-0 Seedlings

For 36 of the 50 seed sources, data were available (table 1) on the weight per thousand of clean seed and the dry weight of a sample of 2-0 nursery-grown seedlings. A regression analysis (table 2 and fig. 1) of these 36 paired values showed that average seed weight and dry weight of 2-0 seedlings were significantly related. The heavier seed tends to produce heavier seedlings than does the smaller or lighter seed.

Seed Weight & Green Weight Of 2-1 Seedlings

When the Kane plantation was being established, a series of 150 measurements of the weight of 14-tree bundles of 2-1 red pine stock was made. The purpose of these meas-

Table 1.--Seed characteristics and nursery behavior of red pine seed collections used in Kane test plantation

Seed-source region and collection number	Seed characteristics			Nursery behavior			
	Clean weight per M	Cleaned seeds per lb.	Germination at 30 days	Germination	Survival		Average dry weight of 2-0 seedlings
					At 1 year	At 2 years	
	Grams	Number	Percent	Percent	Percent	Percent	Mg.
1. Lower Michigan							
29	8.48	53,490	52	60	51	50	104
54	8.67	52,308	96	56	48	46	97
210	8.78	51,663	85	86	81	79	103
213	9.31	48,722	94	80	73	72	118
2. Central Wisconsin							
60	7.99	56,760	48	69	69	67	82
61	9.77	46,419	35	25	20	18	107
64	9.14	49,619	64	67	54	54	116
104	9.55	47,497	91	88	83	82	122
108	9.62	47,152	95	77	68	68	122
157	8.41	53,936	97	81	72	71	101
3. Northeastern Wisconsin- Southern Upper Peninsula of Michigan							
10	7.60	59,726	45	38	29	28	--
12	8.01	56,619	72	47	43	41	89
16	8.34	54,388	--	75	65	63	90
19	8.12	55,852	49	44	33	33	85
222	9.24	49,901	91	80	71	69	118
227	11.20	40,500	94	96	92	91	116
230	7.93	57,200	97	86	77	76	91
268	7.86	57,710	66	--	--	--	--
298	9.78	46,368	89	--	--	--	--
295	8.72	52,018	86	--	--	--	--
4. New York							
294	8.91	50,909	28	--	--	--	--
5. Northeastern Minnesota							
35	7.89	57,480	32	18	16	14	66
36	7.11	63,797	58	72	63	62	66
38	8.15	55,646	72	34	30	30	78
299	8.82	51,428	82	--	--	--	--
6. Brainerd-Cameron (Minnesota & Wisconsin)							
74	9.30	48,765	96	54	36	35	93
75	9.94	45,625	71	78	76	74	91
159	8.08	56,139	96	92	86	86	103
161	9.87	45,957	81	84	76	74	128
174	6.96	65,172	87	72	65	63	80
7. Head of the Lakes (Northern Wisconsin)							
47	8.83	51,360	74	41	39	36	73
49	8.06	56,267	50	62	59	58	80
165	7.71	58,833	92	90	81	80	96
8. Pennsylvania							
267	10.59	42,833	53	--	--	--	--
9. Massachusetts							
123	9.86	46,004	56	74	66	65	124
10. Northern Upper Peninsula of Michigan							
21	7.51	60,388	54	51	44	40	84
235	8.05	56,348	72	--	--	--	--
237	7.40	61,297	71	--	--	--	--
240	8.91	50,909	98	--	--	--	--
246	8.29	54,716	97	--	--	--	--
11. Maine							
293	7.63	58,571	87	--	--	--	--
12. Northwestern Minnesota							
121	7.10	63,887	73	59	54	52	92
144	5.38	84,312	91	80	73	69	57
178	6.94	65,360	92	77	71	69	100
179	7.04	64,432	63	82	72	70	85
181	8.13	55,793	39	65	54	52	88
184	9.45	48,000	62	65	57	57	85
188	6.42	70,654	98	78	72	70	62
284	7.05	64,340	54	--	--	--	--
324	7.75	58,529	81	--	--	--	--

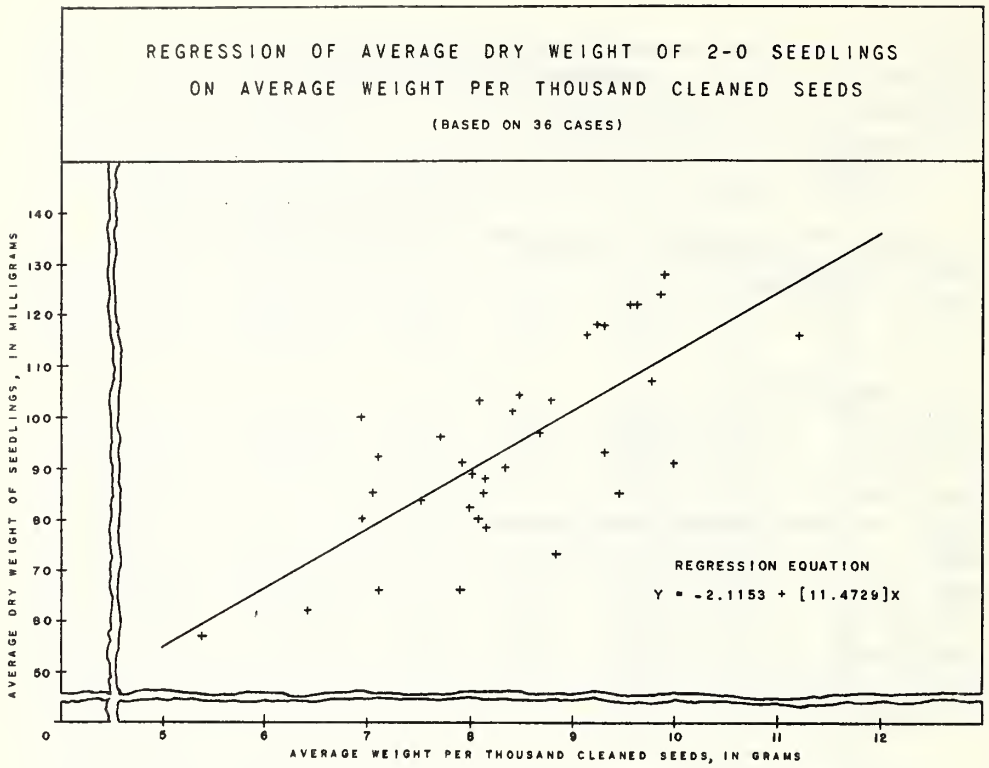

Figure 1.--A significant relationship was found between seed weight and the dry weight of 2-0 seedlings.

urements was to determine the variability of the red pine seedlings from 50 different seed sources before planting (fig. 2). Later the initial green weights could be compared with data on survival and seedling development.

Soil and moss were washed off the roots of the seedling bundles, and the bundles were swished in the air five or six times to remove excess water. The bundles were weighed on a beam balance, which was sheltered from the wind by a tent. Weights were read to the nearest 1/10 gram. After weighing, the seedlings were planted. Plantation arrangement and planting methods are described by Hough (4) in his report on the tree-race study.

The green weights of the 14-tree bundles were compared with data on seed weight and dry weight of 2-0 seedlings for the 36 seed sources for which data were available. Averages for three bundles for each of the 36 seed sources were used.

Regression analyses revealed no significance in these comparisons, although the relationship of the green weight to seed weight did approach significance at the 5-percent level (table 2).

Table 2.--Summary of regression analyses for red pine study at Kane test plantation

Regression of--	Regression coefficient (b)	Standard error of b (S_b)	Test of significance ($t = \frac{b}{S_b}$)	Regression equation ($Y = a + bx$)
Dry weight of 2-0 seedlings on average weight per 1,000 clean seed.	11.4729	1.81238	6.330*	Y = 2.1153 + (11.4729)X
Green weight of 14-tree bundle of 2-1 stock on average weight per 1,000 clean seed.	3.7907	2.22854	1.701**	Y = 76.57813 + (3.7907)X
Average leader length of 2-2 stock on average green weight of 14-tree bundle of 2-1 stock.	0.010796	0.0009699	11.131*	Y = 0.60298 + (0.010796)X
Average total height 5 years after planting on average green weight of 14-tree bundle of 2-1 stock.	0.005887	0.0009861	5.970*	Y = 1.36781 + (0.005887)X
Average total height 10 years after planting on average green weight of 14-tree bundle of 2-1 stock.	0.015995	0.003546	4.510*	Y = 7.75992 + (0.015995)X

* Significant at the 1-percent level, that is, there is less than 1 chance in 100 that such large values would occur by chance.

** Approaches significance at the 5-percent level.

Of course the data were obtained from two different studies, from different samples of stock, were measured with different degrees of accuracy, and were related only in that the same seed-source collections were used to produce the stock. The fact that variations in green weights were reduced by averaging the three groups of seedlings for each seed source may have affected the sensitivity of the statistical analysis.

One can say only that, with the data available, it has not been possible to bridge the gap between results obtained in the Lake States (seed weight and dry weight of nursery-grown seedlings) and in Pennsylvania (green weight and seedling height growth).

SEEDLING WEIGHT & HEIGHT GROWTH

Growth of the seedlings in the Kane plantation was measured at the end of the first growing season, the fifth growing season, and the tenth growing season. Analysis of the measurements shows that the heavier 2-1 planting stock consistently put on the best growth.

First Growing Season

Measurements of 2,100 trees in the plantation were made in the fall of 1937, at the end of the first growing season. Leader growth was chosen as a better measure of height growth than total height of seedling in an attempt to eliminate such variables as depth of field planting and initial differences in length of nursery-grown tops.

Measurements were made from the base of the leader to the tip of the terminal bud in 1/10 feet, estimating to 1/100 foot. The figures were averaged for each 14-tree row, then they were compared with green weights of the 14-tree bundles before planting.

A regression analysis was made, based on the 150 paired measurements of green weight and leader growth. The relationship between green weight and leader growth was marked. The coefficient of correlation was high: "r" = 0.6750 (a value of 0.208 is significant at the 1-percent level). Figure 3 shows how closely the plotted points, showing averages by 10-gram weight classes, compared with the computed regression line.

After 5 Growing Seasons.

At the end of the fifth growing season, in the spring of 1942, total height of the seedlings was measured. Measurement was taken from ground level at the base of the tree, and was recorded to the nearest 1/10 foot. Few of the trees were more than 5 feet high; so the records of height were made quickly and accurately.

Again regression analysis showed a significant relationship. Agreement between the plotted points and the computed regression line was very close (fig. 4).

Figure 2.--Samples of the 14-tree bundles of 2-1 planting stock. The bundles were weighed before planting. The bundle at the left is representative of large planting stock. The middle bundle is medium stock, that on the right small.

After 10 Growing Seasons.

In the fall of 1947 and the spring of 1948 measurements were made of the growth during the first 10 growing seasons. Total heights were measured.

An extensible measuring pole was used in this measurement. Measurements were taken to the nearest 1/10 foot. The density of lower branches and the greater height of the trees made this measurement rather difficult. Some difficulty was experienced in determining average ground level at the base of the trees, because of the build-up of litter and irregularities in the surface. An observer was needed to call out the point when the measuring rod reached the level of the top of the leader. But in no cases did errors of measurement exceed 3/10 foot for an individual tree.

Similar statistical analyses were made to determine the relationship between initial green weight of the seedlings and subsequent height growth. Because of the excellent survival, adequate samples could be taken for this analysis. The analysis of growth data at 10 years showed that the relationship found after one and five growing seasons still held true (fig. 4)--contrary to the often-expressed belief that initial differences in size of weight of planting stock disappear soon after planting.

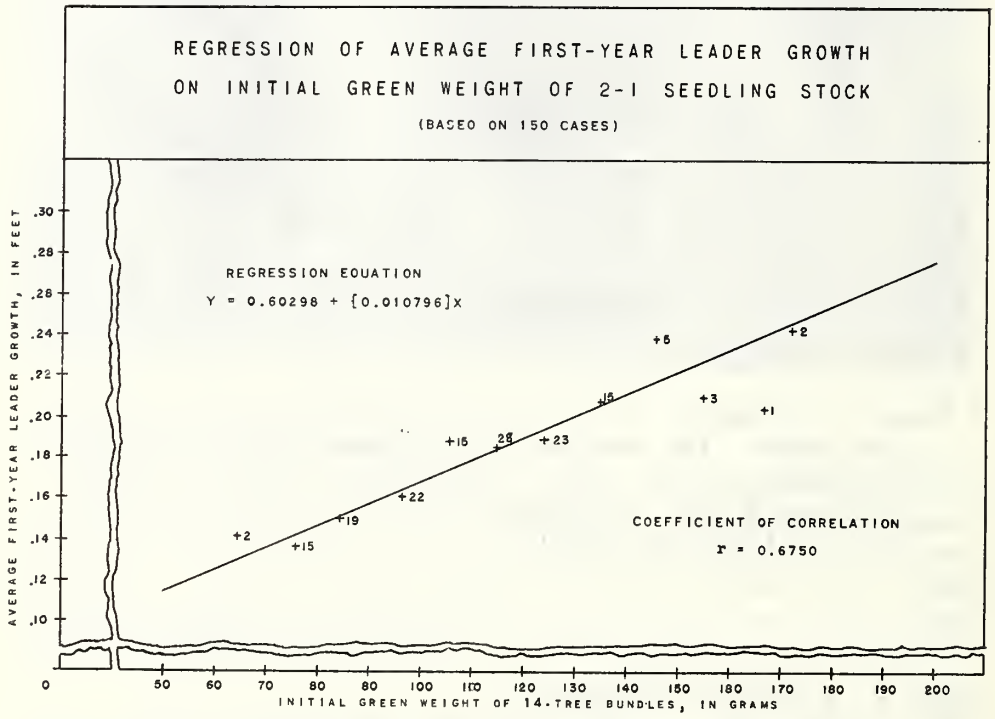

Figure 3.--A marked correlation was found between leader growth and green weight of seedlings.

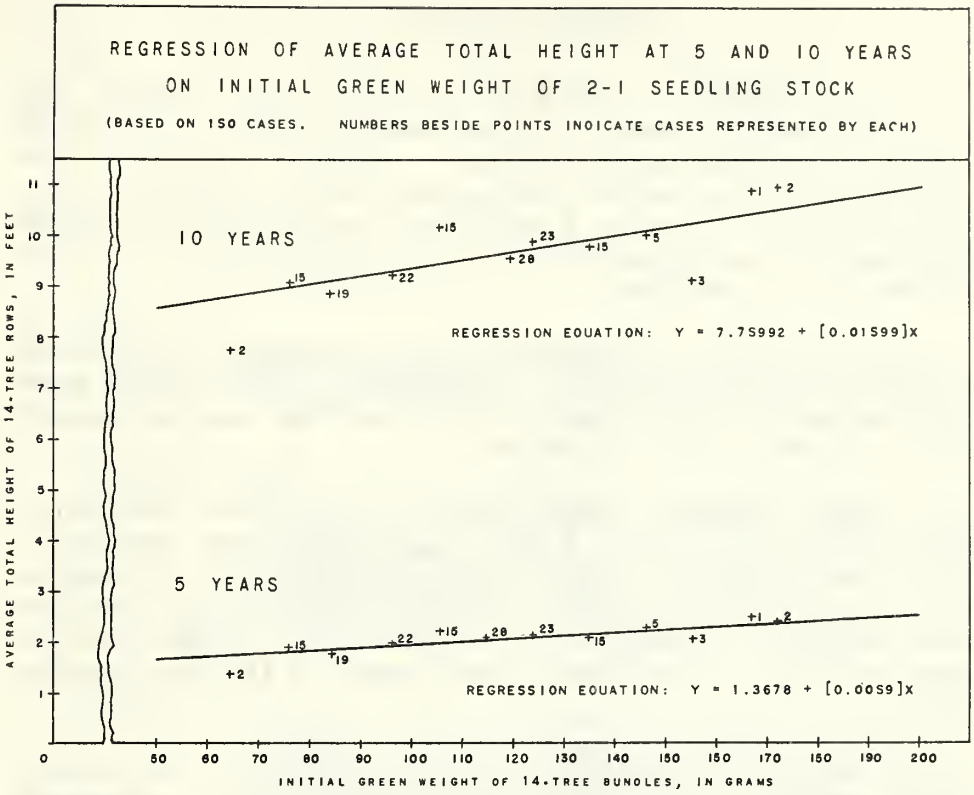

Figure 4.--The correlation between tree growth and the green weight of the 2-1 planting stock continued after 10 growing seasons. Note the difference in the slope of the regression lines. The gap in growth between the larger planting stock and the smaller is expected to widen as the larger trees attain dominance.

Agreement between plotted points and the regression line was good but there was somewhat more scatter at the 10-year period, although green weight and total heights were still significantly related. Even more important was the apparent difference in degree of slope between the regression lines for the 5-year period and the 10-year period. A statistical test for the value of "t" proved that this difference in slope, or in the coefficient of regression, was a real difference. Computed "t" was 2.746, based on 295 degrees of freedom, compared to a tabular value of 2.592. The regressions at 5 and 10 years thus showed significant differences at the 1-percent level.

CONCLUSIONS

Correlations were found between seed source and weight of red pine seed, in data made available by the Lake States Forest Experiment Station. However, because of the variations in seed weight within seed-source regions, seed weight cannot be used as a guide for identifying seed source. Correlations were also found between seed weight and dry weight of 2-0 seedlings.

In the test plantation at Kane Experimental Forest in northwestern Pennsylvania, significant relationships were found between green weight of 2-1 seedlings and subsequent height growth in the plantation.

But attempts to relate growth at the Kane plantation back to the seed sources in the Lake States were unsuccessful. No correlation could be found between the dry weights of 2-0 seedlings reported by the Lake States Station and the green weights of bundles of 2-1 seedlings (grown from the same seed collections) that were planted in the Kane plantation.

In the Kane plantation study, comparisons of initial green weight of red pine seedlings and their subsequent height growth indicated that red pine trees that have an early advantage of greater weight, and thus are larger in over-all size of shoot and roots, tend to grow at a greater rate during the second 5 years after plantation establishment than during the first 5 years.

Conversely, the growth rate of trees in the medium and small weight classes tends to fall off. This widens the gap in size between the upper and lower height classes at 10 years as compared to 5 years.

Should this trend continue in the future, the eventual dominant crop trees in the plantation will doubtless be mostly those that were among the heavier seedlings at time of planting. With each successive growing season these larger trees may be expected to make the greatest gains.

With greater total height one may also expect a greater tendency to crown expansion and an expression of dominance over the smaller trees. Up to the time of the 10-year measurement there had been little competition for growing space; closure of the lower branches was just beginning.

Increasing competition for space above and below ground will accelerate this process of favoring the larger and more vigorous trees over the smaller and less-rapidly-growing trees.

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